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Overview of WHO (World Health Organization) Environmental Health Criteria 35 on Extremely-Low-Frequency (ELF) Fields

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OVERVIEW OF WHO ENVIRONMENTAL HEALTH CRITERIA 35 ON EXTREMELY-LOW-FREQUENCY (ELF) FIELDS

by

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16. ABSTRACT

This paper summarizes and reviews the document World Health Criteria 35. The purpose of the Criteria 35 is to provide information for health authorities and regulatory agencies on the possible effects of extremely-low-frequency (ELF) electric and magnetic fields on human health and to give guidance on the assessment of risks from occupational and general population exposures. The Criteria Document includes a review of biological effects on human beings and animals exposed to ELF fields in the frequency range of 0-300 Hz with emphasis on power (50- and 60-Hz) electric fields. Subjects reviewed in the document include the physical characteristics of ELF fields, measurement techniques and dosimetry, levels of exposure from devices in common use, mechanisms of interaction, biological effects in animals and animal tissues, human studies, health risk evaluation, and guidance on the development of protective measures such as regulations and safe-use guidelines. The document also identifies areas in which uncertainties exist in the literature and where further research is needed. The goal was to provide useful information for the development of national protection measures against ELF fields.

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BACKGROUND

A program on the integrated assessment of the health effects of environmental pollution was started by the World Health Organization in 1973 following the recommendations of the United Nations Conference on the Human Environment held in Stockholm in 1972 and in response to a number of World Health Resolutions. The program is known as the WHO Environmental Health Criteria Program, and it is supported by the Environmental Fund of the United Nations Environment Program.

In 1974 the International Radiation Protection Association (IRPA) formed a Working Group (International Nonionizing Radiation Committee, INIRC) on nonionizing radiation. The IRPA/INIRC reviewed the scientific literature on nonionizing radiation and made assessments of the health risks of exposure to humans of such radiation. Based on the documents developed in conjunction with WHO, the IRPA/INIRC recommended guidelines on radiofrequency exposure limits, drafted codes of safe practice and worked with other international organizations to promote safety and standardization in the nonionizing radiation field.

COMMITTEE MAKE-UP

In early March of 1984, a joint WHO/IRPA Task Group on Environmental Health Criteria for Extremely-Low-Frequency Fields met in Geneva. The Task Group reviewed and revised a draft criteria document, made an evaluation of the health risks of exposure to extremely-low-frequency electromagnetic fields, and considered rationales for the development of human exposure limits. Members of this Task Force were:

Dr. J. Bonnell, Central Electricity Generating Board, London, England.

Dr. B. Bosnjakovic, Ministry of Housing, Physical Planning, and Environment, Rijswijk, The Netherlands.

Dr. J. Cabanes, Medical Committee, Electricité de France-Gaz de France, Paris, France.

Dr. M. Grandolfo, Laboratory of Radiation, Institute of Public Health, Rome, Italy.

Dr. B. Knave, Research Department, National Board of Occupational Safety and Health, Solna, Sweden.

Dr. J. Kupfer, Occupational Hygiene Standardization, Central Institute of Occupational Medicine, Berlin, German Democratic Republic.

Dr. R. Phillips, Biology Department, Pacific Northwest Laboratory, Richland, Washington, USA.

Dr. A. Portela, Institute of Biophysical Research, National Council of Scientific and Technical Research, Buenos Aires, Argentina.

Dr. M. Rapacholi, Royal Adelaide Hospital, Adelaide, South Australia.

Dr. A. Shepperd, J.L. Pettis Memorial Hospital, Loma Linda, California, USA.

Mrs. A. Duchêne, Commissariat à Énergie Atomiqu e, Déparament de Protection Sanitaire, Fontenay-aux -Roses, France (IRPA Secretariat).

Mr. G. Ozolins, Manager, Environmental Hazards and Food Protection, Division of Environmental Health, WHO, Geneva, Switzerland.

Dr. M. Shore, National Center for Devices and Radiological Health, Food and Drug Administration, Rockville, Maryland, USA (Advisor).

The document reviewed and revised by the Task Force was a combination of drafts prepared by Drs. A. Sheppard and W.R. Adey (J.L. Pettis Memorial Hospital, Loma Linda, California, USA), Drs. M.G. Shandala and V. Akimenko (A.N. Marzeev Institute of

General and Communal Hygiene, Kiev, USSR), and Dr. P. Czerski and Mr. J.C. Villforth (National Center for Devices and Radiological Health, US Department of Health and Human Services, Rockville, Maryland). The drafts were integrated at working group meetings in Grenoble (1980) and Paris (1982). A subsequent draft was prepared by Dr. P. Czerski, Dr. B. Bosnjakovic, Dr. M. Repacholi, Dr. V. Akimenko, Dr. M. Grandolfo, Dr. J. Cabanes and Mrs. A. S. Duchêne at the WHO/IRPA working group in Paris in 1983. A final draft, incorporating the comments by WHO reviewers and many international experts, was prepared by Drs. Repacholi and Sheppard in December 1983. After review and revision of the final draft by the Task Force, the Criteria document was published in the fall of 1984.

PURPOSE AND SCOPE

The purpose of the document was to provide information for health authorities and regulatory agencies on the possible effects of ELF field exposure on human health, and to give guidance on the assessment of risks from occupational and general population exposure. The document also identified areas in which uncertainties exist in the literature and where further research is needed. It was hoped that the criteria document would provide useful information for the development of national protection measures against ELF fields.

The Criteria document includes a review of the scientific literature on the biological effects on human beings and animals exposed to extremelylow-frequency electric and magnetic fields in the frequency range of zero to 300 Hz, with emphasis on power

frequency (50- and 60 Hz) electric fields. Effects of co-generated ozone, noise, ultraviolet radiation and radiofrequency radiation from corona discharges are discussed only briefly. The effects of contact currents were not considered in detail since restrictions of leakage currents from applicances and electrical devices was already treated by national and international standards.

Subjects reviewed in the document include the physical characteristics of ELF fields, measurement techniques and dosimetry, sources and applications of ELF, levels of exposure from devices in common use, mechanisms of interaction, biological effects in animals and animal tissues, human studies, health risk evaluation, and guidance on the development of protective measures such as regulations or safe-use guidelines.

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

In Vitro Studies

Biological studies on cells and tissues (in vitro studies) have been conducted to elucidate mechanisms of interaction of ELF fields with biological tissues and cells and to provide information on endpoints to search for with animal (in vivo) studies. In vitro studies have included excised and cultured tissues, cell biochemistry, neurophysiology, and growth of bone tissue. Electric fields have been reported to effect endocrine gland secretion, response to hormonal stimulation, brain calcium ion exchange, immunoreactivity of lymphocytes, electrical excitability of neural tissue, and tissue growth rates. Some of these studies have revealed ELF effects occurring within certain limited ranges (windows) in frequency and amplitude.

Experimental Animal Studies

Studies with laboratory animals exposed to ELF electric fields up to 100 kV/m have revealed effects on components of the nervous system, including synaptic transmission, on circadian rhythms, and on the biochemical properties of brain tissue. Results of behavioral studies suggest that the nervous system may be affected by an ELF electric field that is far too weak to stimulate cell firing, although in vivo studies often do not exclude the possible role of tactile sensory phenomena (e.g., skin and hair receptor stimulation).

Numerous investigators have examined peripheral blood composition and biochemistry of exposed animals and results are inconsistent. Reported changes in the blood picture are usually small deviations from normal expected values and within physiological norms. Results of studies on immunocompetence, genetics and cardiovascular function appear to be negative.

Effects on Man

Information on effects of ELF fields on humans come from three sources: surveys on the state of health of high-voltage substation workers and high-voltage line maintenance crews; results of studies on volunteers exposed to electric fields; and mortality and epidemiological studies.

Surveys on the health of high voltage workers have produced conflicting results. Reports by Soviet authors of an increased

incidence of subjective complaints attributable to effects on the nervous system and shifts in blood biochemistry were not found by other authors. Two limitations of such studies have been small sample sizes and the lack of reliable data on exposure intensity and duration.

A few studies on volunteers exposed to electric fields up to 20 kV/m under laboratory conditions have confirmed the existance of slight changes in peripheral blood cells and biochemistry similar to those observed in experimental animals. Such changes, although statistically significant, have been small and fall within normal physiological limits.

Several recent mortality and epidemiological reports have provided some preliminary data which suggest an increase in the incidence of cancer among children and adults exposed to magnetic fields close to various types of electrical power lines or devices. The preliminary nature of these studies, the low levels of exposure, and the relatively small increase in reported incidences suggest that although such data cannot be dismissed, there must be considerable study before such data can serve as useful input for risk assessment.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the literature review and by lengthy discussions among Task Force members, a consensus was reached on ten (10) recommendations and conclusions regarding possible effects of electromagnetic fields on human health, and for guidance on

the assessment of risks from occupational and general population exposure. The 10 recommendations and conclusions were*:

1. *In order to relate biological findings from in vitro and in vivo studies on experimental animals to human beings, it is recommended that dosimetry studies should be continued to measure and relate external electric field strengths and internal current density distributions in the whole body of both animals and human beings.*

2. *From studies on man and animals, observed sensitivities are consistent with two proposed models, one on the basis of stimulation of peripheral sensory receptors in strong local electric fields at the body surface, and the other on the basis of current densities induced in the extracellular fluid. It is recommended that models be devised that correlate exposure and biological effects in terms of physical factors, such as surface electric field, tissue current density, spark discharges, and waveform.*

3. *The continuation of basic research on electric and magnetic field interaction mechanisms is strongly recommended. Investigations should be conducted on the possible synergism or antagonism of field influences with physical and chemical agents, since such data are not available.*

4. *In some studies, restriction of ELF effects to certain "windows" in frequency and amplitude has been reported. It is recommended that the window concept be further investigated to determine the applicability of data obtained with various frequencies and waveforms, and to relate the findings to potential health detriment in human beings.*

5. *Studies have been performed on workers with long-term exposure to electric and magnetic fields, but no adverse health effects have been identified. However, these studies were not designed to evaluate effects on reproductive functions, or long-term carcinogenic risks. In two of the studies, electric field exposure was carefully evaluated, and it was found that average exposures in the occupationally-exposed groups were remarkably low.*

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*Quoted from Environmental Health Criteria 35, Extremely Low Frequency (ELF) Fields, World Health Organization, Geneva, 1984, pp 16-18.

A suggestion of increased cancer incidence has been reported by a number of investigators who have examined occupational and general population groups exposed to electric and magnetic fields. The studies performed have serious deficiencies in epidemiological design and do not adequately characterize levels and duration of exposure.

The limited knowledge of the potential human health risk associated with exposure to electric and magnetic fields makes it imperative that well-designed epidemiological studies should continue to be undertaken to provide a firmer basis for risk assessment.

6. *Occupational exposure to strong electric fields is generally intermittent and of short duration; exposed populations have been identified, and there are some limited data based on practical experience. At field strengths where spark discharges are prevalent, prolonged exposures may impair performance. Such exposures should be avoided, where possible.*

7. *Linemen working on energized extra- or ultra-high-voltage conductors experience extreme electric field conditions, and the use of appropriate protective clothing or devices is desirable.*

8. *Whilst it would be prudent in the present state of scientific knowledge not to make unqualified statements about the safety of intermittent exposure to electric fields, there is no need to limit access to regions where the field strength is below about 10 kV/m. Even at this field strength, some individuals may experience uncomfortable secondary physical phenomena such as spark discharge, shocks, or stimulation of the tactile sense.*

9. *It is not possible from present knowledge to make a definitive statement about the safety or hazard associated with long-term exposure to sinusoidal electric fields in the range of 1 - 10 kV/m. In the absence of specific evidence of particular risk or disease syndromes associated with such exposure, and in view of experimental findings on the biological effects of exposure, it is recommended that efforts be made to limit exposure, particularly for members of the general population, to levels as low as can be reasonably achieved.*

10. *In principle, electric and mangetic field interference with implanted cardiac pacemakers can lead to reversion to a fixed rate, but cessation of stimulation is possible. Direct interference has not been reported in fields below 2.5 kV/m. Although body currents produced by contact with a vehicle in a weaker field may cause interference, the risk of pacemaker reversion is believed to be slight. It is recommended that pacemaker designers and manufacturers of other similar electronic equipment ensure that their devices are resistant to failures caused by electric or magnetic field-induced currents.*

It is important to note that a consensus was not reached among Task Force Members on specific field intensities or durations of exposures that could be considered safe or potentially hazardous. Because of the uncertainties in the research literature and lack of cqnvincing evidence that exposure to ELF electric and magnetic fields produce overt pathological damage, establishment of specific field strength limit was not considered possible at the present time. The Task Force members were in agreement that additional research was needed to address unresolved issues on carcinogenesis, low-level effects at certain windows of frequency and intensity, and dosimetry for the extrapolation of data obtained from experimental animal studies to human beings.

SIGNIFICANCE OF WHO REPORT TO UTILITIES

As stated in the Purpose and Scope of this paper, the WHO Environmental Health Criteria 35 document was written to provide information for health authorities and regulatory agencies on the possible effects of ELF field exposures on human health, and to give guidance on the assessment of risks from occupational and

general population exposure. Such information should prove invaluable to Utilities in setting safe operating procedure for high-voltage line workers and switchyard workers who may be exposed to high electromagnetic field strengths in the course of their work. Also, since electric fields up to 12 kV/m can exist within the rights-of-ways of high voltage transmission lines and may exceed 2-3 kV/m at the edges of rights-of-ways, information in the WHO document is relevant to siting and rights-of-way practices of the utilities.

The WHO document provides an excellent summary review of the international scientific literature up to 1983 on the biological effects of ELF electromagnetic fields. Based on the literature review, and by consensus of the Task Force members, it was concluded that it was not possible to make a definitive statement about the safety or potential hazards associated with long-term exposure to sinusoidal ELF electric fields in the range of 1-10 kV/m. Although there was no conclusive evidence of risk or disease associated with exposure to such fields, it was recommended that efforts be made to limit exposure of the general population to as low as can reasonably be achieved (ALARA). This important caveat was included in the document because of concerns expressed by several members of the Task Force regarding research finding at that time, 1983, demonstrating biological effects of ELF fields from several in vitro and in vivo studies. Since 1983, when the WHO document was written, results from several of these studies of concern have been replicated and extended. Results from

studies during the past several years indicate that the ELF magnetic field rather than the electric field may be the important factor in producing some of the reported effects. Whether exposure to such fields represent a human health hazard or risk has not been established. This question can only be answered by additonal research. Of particular concern is the relationship of exposure to ELF electric and magnetic fields to the incidence of cancer, reproductive and development processes, circadian rhythm and cell function.

DISCLAIMER

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